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DIFFERENTIAL EFFECTS OF WAVE FORM AND THE SUBJECT'S POSSIBLE TEMPORAL LOBE SIGNS UPON EXPERIENCES DURING CEREBRAL EXPOSURE TO WEAK INTENSITY MAGNETIC FIELDS

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Abstract. In three separate experiments a total of 85 male and female university students were exposed within a Ganzfeld setting to weak (1 mG, 100 nT), complex magnetic field patterns. They were applied across the temporal lobes and generated by computer software. When the patterns were rotated spatially over the

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temporal lobes the numbers of subjective experiences that simulate possible temporal lobe signs and symptoms were markedly increased and qualitatively more extreme than those evoked when the fields were not rotated. A 16 Hz pulsed square wave generated more experiences of thought intrusion than a 4 Hz wave. A positive-feedback ringing wave presented at 4 Hz evoked more visual memories and images than the mirror image of the same wave; the effect was only apparent when the subject's quantitative scores for possible temporal lobe signs was covaried. Only those subjects who displayed above average temporal lobe signs and were exposed to a burst-firing wave pattern for one second once every 4 seconds (a condition intended to release endogenous opiates), reported more emotional perturbations when the state was disrupted relative to subjects who were exposed continuously to the same pattern. The results indicate that a person's temporal lobe profile affects the types and intensities of experiences that are reported when very weak magnetic fields are applied through the human brain.

Introduction

Both technical and metaphorical arguments (1-2) have been developed to suggest that optimal temporal patterns (wave forms) of applied magnetic fields should interact with the neuro-electrical ensembles in the human brain. The most probable focus of interaction between applied magnetic fields and brain space should occur within the deep temporal lobes. Within this region the most electrically labile and sensitive portions of the human brain, the amygdala and hippocampus, access memory for and attribute meaning to sensory input (3).

Normal or artificial (surgical) stimulation of these limbic structures is associated with neuropsychological phenomena that are fundamental to human experience. They include vivid visual sensations, memory fragments, a sense of intense meaning, intrusions of ideas or images, mystical experiences and alterations of boundaries concerning the sense of self (4-5). Several researchers, such as Vernon Neppe (6), Bear and Fedio (7) and Persinger and Makarec (8) have suggested that a continuum of possible temporal lobe signs exist within the normal population. They reflect the intrinsic electrical lability of deep temporal lobe structures. The arguments for this supposition have been developed previously (1,8,9).

If the technical and metaphorical arguments are correct, then simple, applied magnetic field shapes such as sine waves, should be minimally effective unless the current densities are sufficient to produce coercive and potentially dangerous disruptions in neuronal ensembles. Instead, optimal induction and subsequently maximal subjective alterations, should occur when the temporal structure of the applied magnetic field simulates those that are indigenous to the amygdala and hippocampus. They typically generate complex patterns that are often described as a "burst firing" profile (10).

The second important variable that would determine the detectability of any effect from weak magnetic field patterns, applied across the temporal lobes, would involve their intrinsic lability. If a continuum of temporal lobe lability exists, then the applied fields would only exacerbate experiences and symptoms that are already present. Consequently, quantitative inferences of the lability of the subject's temporal lobe activity would be required. Their removal by covariance would be essential in order to reveal the expected small effects from any applied magnetic field pattern.

In a previous experiment (1), we explored the various measures that might optimally reveal the electroencephalographic, electrocardiological and phenomenological consequences of brief exposures of the human brain to biofrequency magnetic fields. We found that 20 items, completed by the subject at the end of a 30 minute experimental period, could discern weak but internally consistent effects of field exposure. These items composed the Subjective Experience Questionnaire (SEQ); they were derived from an inventory that infers possible temporal lobe symptoms and signs (8,11). Aggregates of these 20 items were determined a priori according to their shared features of sense modality (1). In the following studies, we decided to utilize aggregates of items that were based upon empirical criteria.

To achieve this, the 20 SEQ items were factor analyzed (principal component analyses) for 100 subjects who had been exposed to the ganzfeld setting. After varimax rotation, six factors emerged; their names (eigen values and percentage of explained variance, in parentheses) are vestibular effects (4.09, 22%), depersonalization (1.69, 9%), emotions (1.63, 9%), out-of-body experiences or OOBE (1.36, 7%), old memories (1.14, 6%) and thought intrusions (1.10, 6%).

The items (correlation coefficient in parentheses) that significantly ($r > 0.40$) loaded on the first three factors were: Vestibular: I felt dizzy or odd (0.57), There were tingling sensations (0.82), There were pleasant vibrations moving through my body (0.77) and I heard a ticking sound (0.55); Depersonalization: I felt the presence of someone or something (0.43), I experienced fear or terror (0.59), I felt as if I were somewhere else (0.40), The same idea kept occurring (0.64) and I felt as if I were spinning around (0.54); Emotions: I experienced anger (0.75), I

experienced sadness (0.65) and There were images from a dream I had (0.66).

For the remaining three factors, the items and their loadings were: OOBE: I felt as if I had left my body or was detached from my body (0.63), The experiences did not come from my own mind (0.48) and There were odd smells (0.73); Old Memories :I saw vivid images (0.76), I felt as if I were somewhere else (0.44), and "I experienced thoughts from childhood" (0.64); Thought Insertion: I felt the presence of someone or something (0.56), The experiences did not come from my own mind (0.44). There were odd tastes in my mouth (0.66) and The red light became brighter or darker (0.61). The score for each of the six clusters was computed by SPSSX software by obtaining the means of the items for each cluster.

Although these clusters were empirically determined they were concordant with the aggregates of items, computed according to modality for the Ruttan, et al. study (1). Scores on the vibrational experience cluster were significantly correlated (Pearson r) only with vestibular effects (0.86) and other modalities (0.74) while depersonalization was associated with vestibular (0.73) and depersonalization (0.78) from the other study. Scores on the emotion cluster were correlated with affect (0.76) while the OOBE was correlated with depersonalization (0.82). Finally, old memory scores and imagination (0.81) and depersonalization (0.63) were most correlated, while thought intrusions were correlated with the depersonalization (0.72) and other modalities (0.49) clusters.

These factors were used to discern the possible effects of various temporal structures of applied magnetic fields. We determined that six subjects per field condition-frequency or field condition cell should be employed in each experiment. With this

number of subjects per cell any statistically significant effect would explain at least 25% of the variance. An effect of this magnitude or greater was considered critical in light of our interest in the application of these procedures to cognitive therapy. Procedures that induce substantial alterations in the subject's or patient's physiological and psychological states are a prerequisite for significant changes in behavior. Such state dependence, most frequently evoked by pharmacological treatment, allows the criterion or adjustive behaviors to be rewarded and strengthened.

Experiment I

Subjects

Twelve male and 12 female university students served as subjects. They were rewarded for participation by a 2% bonus that was added to their final grades in a course that was not taught by the authors. The mean age was 25 years and the range was between 20 and 37 years.

Procedure

Within one week before the exposure, the subjects completed the PPI. Each subject was tested singly; he or she was escorted into the acoustic room (1) and asked to sit in a comfortable chair. The background magnetic field strength within the 1 Hz to 1 kHz range was 0.025 mG (2.5 nT). The subject was told that the experiment was involved with imagery and that he should describe any experiences that occurred. Electrodes were attached in order to obtain heart rate. Two

halves of a ping-pong ball, filled with cotton and fashioned as goggles served to produce an opaque field. A red (photographic developing) light was placed 1 meter in front of the subject.

Half of the number of subjects (equal number of males and females) was exposed to the solenoid field as described previously (1,12) while the other half were exposed to the rotating magnetic field (RMF) condition. The two solenoids were placed over the T3 and T4 region of the skull. The magnetic fields were generated by a Health-Schlumberger Function Generator. Half the number of subjects in the solenoid condition received the 4 Hz treatment while the other half received the 16 Hz treatment.

The remaining subjects were exposed to the RMF. They wore a modified motor cycle helmet (Canada CSA/DOT model 100; size M) within which four sets of small solenoids (250 ohm coils from 5 V DC relays, with reed removed and replacement by a small steel finishing nail) had been implanted at the level of the temporal planes. A Gerbrands 300 series milli-second timer (sequencer) changed the pair of solenoids that were activated by the function generator once every 0.5 seconds such that the presentation of the field rotated counterclockwise on the left and clockwise on the right around an ellipsoid with a major axis of 7.6 cm and a minor axis of 5.1 cm (one complete cycle every 2 seconds). This signal source was sent to the signal distribution interface (semiconductor switches) that was controlled by the Gerbrands sequencer. (The signal distribution interface had been constructed to receive input from either a computer or the function generator.) From the sequencer the signal was sent through the patchcord panel of the acoustic chamber into the solenoids or the helmet. The field strengths

within the area in which the subjects brain was exposed was not stronger than 1.5 mG (150 nT) as measured by a model 113-2 power frequency field meter.

The instructions were then repeated to the subject. A tape that generated exotic music, primarily electronic and repetitive ticking sounds, was activated. The experimenter switched off the chamber lights and left. During the next 30 minutes, the field was turned on and off for 5 consecutive minutes resulting in 3 pairs of off-on blocks. Heart rate was measured on one channel of a P79 Grass polygraph. The presence of the field was verified by a sensor that was connected to the polygraph record. Statements by the subject were recorded; however the transcripts were not analyzed for this study.

After the 30 minute period, the equipment and monitors were removed from the subject (quickly but comfortably). Each subject was then asked to complete the SEQ. The rating scale included: never (0), at least once (1) and frequently (2); an additional no-yes item was asked: "The visual experiences were primarily in the upper half of my visual field" in order to infer temporal lobe stimulation adjacent to Meyer's loop (13). The subject then left the experimental area.

Heart rate was determined by counting the numbers of QRS within the first minute and last minute of each of the 6 (3 pairs) blocks. The six scores for the factored clusters of the SEQ were calculated as noted in the introduction. The CPES (complex partial epileptic symptoms) cluster (8) from the PPI (Personal Philosophy Inventory) was calculated for each subject. The mean and standard deviation of this score for the subjects in this experiment was 29(17)%, which is within the normal range (8).

Two way analyses of variance as a function of exposure mode (solenoid vs RMF) and frequency (4 Hz vs 16 Hz) were completed for each of the 6 clusters. Chi-square analyses was completed for the item referring to upper visual field experiences. To discern possible differential changes in experiential frequencies across the six clusters, a three way analyses of variance with one repeated level (the clusters) was also performed. A four-way analyses of variance, with two levels repeated (field off-field on; blocks 1-3) and two not repeated (exposure mode and frequency) was completed for heart rate. Because there were no significant sex effects as determined by an initial ANOVAs that included this variable, this factor was not included.

Results

Means and standard deviations for the cluster scores as a function of mode of field presentation (static vs time-varying) and frequency (4 Hz vs 16 Hz) are shown in Table 1. Two-way analysis of variance (ANOVA) demonstrated no statistically significant main effects or an interaction for the vibration or emotion clusters. Subjects within the rotating magnetic field condition reported more frequent experiences (percent refers to explained variance) within the depersonalization cluster [$F(1,20)=10.99$, $p<0.01$; 35%], the OOBE cluster [$F(1,20)=10.32$, $p<0.01$; 36%] and memories cluster [$F(1,20)=18.91$, $p<0.01$;50%] relative to subjects who were exposed to the solenoid setting. There were no significant interactions between mode of presentation and frequency. Covariance for CPES before the analyses reduced the F values of the 3 clusters (F=6.83, 7.83 and 12.70, respectively) but did not change the level of

Table 1. Means and standard deviations for various clusters of experiences for subjects to which either the solenoid or rotating magnetic field mode and either the 4 Hz or 16 Hz pulsed magnetic fields of about 1 mG were applied across the temporal lobes for 3, 5 minute intervals (n=6/condition).

Cluster	Solenoid				RMF			
	4 Hz		16 Hz		4 Hz		16 Hz	
	M	SD	M	SD	M	SD	M	SD
Vibrations	.5	.3	.9	.3	1.2	.6	1.2	.8
Depersonal.[c]	.2	.3	.6	.3	.9	.3	1.0	.5
Emotional	.1	.2	.1	.1	.2	.2	.4	.1
OOBE[c]	.1	.2	.6	.6	.6	.6	.8	.4
Old memories	.2	.2	.4	.3	1.1	.6	1.2	.3
Intrusions[f]	.2	.2	.4	.3	.2	.2	.5	.4
Total[c,f]	.2	.1	.4	.2	.6	.1	.8	.2
Upper Visual Field	25%		25%		83%		100%	

[c] RMF vs solenoid difference $p < 0.01$

[f] 4 Hz vs 16 Hz difference $p < 0.05$

statistical significance; the effects of the covariate was not significant.

The only significant frequency effect [$F(1,20)=4.59$, $p < 0.05$; 22%] was noted for the intrusion cluster. Subjects exposed to the 16 Hz pulsed field, regardless of mode of presentation, reported more of these experiences than those who were exposed to the 4 Hz condition. Covariance for CPES did not alter the level of significance [$F(1,20)=5.54$, $p < 0.05$; 22%], even though the covariate was significant [$F(1,20)$ =

4.26, p=0.05]. The total score for all items demonstrated a significant mode of presentation [F(1,20) = 32.03, p <0.01, 63%] and frequency [F(1,20)=3.26, p=.05; 10%] effect. Covariance for CPES scores eliminated the statistically significant frequency effect [F=2.45; p >0.05].

Chi-square analyses (chi-square=6.58) indicated a significant (p <0.05) difference in the frequency of references to upper visual field experiences between the two modes of presentation. Subjects who were exposed to the RMF mode reported significantly [F(1,20)=17.30;52%, p <0.01] more visual experiences within their upper visual fields than those who were exposed to the solenoid; there were neither significant frequency nor frequency by mode interactions. Covariance for CPES did not alter the significance (F=12.57) of the effect.

A three-way analyses of variance with one level (all 6 clusters) repeated, revealed a statistically significant [F(1,20)=30.16, p <0.01] increase in the ratings of total experiences within the RMF condition relative to the solenoid mode. Elevated scores within the group (regardless of mode of presentation) exposed to the 16 Hz fields relative to those who received the 4 Hz field was marginally significant [F(1,20)= 3.55, p=.05]; the interaction was not significant. Scores for the different clusters were also significantly different [F(5,100)=11.46, p <0.01] and there was a significant mode by cluster interaction [F(5,100)=2.60, p <0.05]; this was due primarily to the increase in OOBE and old memory experiences in the RMF mode relative to their decrease in the solenoid condition whereas the other experiences remained similar.

A 4-way analyses of variance with two levels repeated (no-field, field; three successive blocks) and two main factors

(mode and frequency) demonstrated no statistically significant main effects. A statistically significant reduction in heart rate (about 2 beats/min) for all modes, frequency and blocks was noted in the field-on condition relative to the field-off condition [$F(1,20)=17.41$, $p< 0.01$); a significant block effect [$F(2,40)=21.63$, $p <0.01$] was noted, due to the gradual reduction in heart rate during the session. There were no other significant main effects or interactions. Covariance for CPES did not change the level of significance for the on-off or block conditions and did not reveal any further statistically significant effects.

Experiment II

The results of Experiment I indicated that the rotating magnetic field generated more experiences suggestive of temporal lobe signs than the solenoid (static space) condition (1). In addition, subjects exposed to the 16 Hz field reported more experiences of "thought intrusion" than those who were exposed to the 4 Hz condition. Although these results could be interpreted as "differential field effects", the strength of the 16 Hz fields were about twice that of the 4 Hz field. In addition, it is possible that the spatial-rotation within the RMF condition may have also produced an intensity difference relative to the static solenoid application.

In order to determine if <u>different wave patterns</u>, not confounded by intensity or application features, could generate differentially more experiences we decided to compare the effect of the square wave condition with a complex wave whose shape differed only in the temporal order of its presentation;

consequently the area under the wave form (the intensity) would remain constant. Morphological complexity of the wave was considered important (1) because we strongly suspect that neuronal ensembles within the temporal lobe respond to current patterns that are more similar to endogenous conditions. In order to increase the likelihood of detecting such an effect, we also decided to increase the duration of a single exposure.

We hypothesized that the effects of the complex wave would be weak and consequently hidden within the large inter-subject variability for possible temporal lobe signs. Because the effects of the field should produce experiences extremely similar to those that are simply quantitatively more prevalent in people with enhanced CPES scores, treatment differences from the magnetic field should be most evident only after these individual differences in CPES scores were accommodated.

The possibility of the subjects' suggestibility either interacting with or confounding the subjective experiences has been a procedural concern. In previous experiments (14,15), we found that certain items of the PPI were significantly correlated with the Spiegel (16) hypnotic induction profile (HIP). It is a composite of measures of responses that are evoked by verbal instruction. The responses include upward eyeroll, floating sensations, amnesia, arm levitation and tingling experiences as well as a total induction score between the values 0 and 10.

Multiple regression analyses of 25 male and 25 female young adults from another study revealed four items: "People tell me that I become excited over insignificant events" "when I see a child starving from hunger on T.V. commercials, I feel sad", I have never had "memory blanks" where I could not recall

previous events (answer no) "At times I feel like smashing things" were correlated 0.66 with the HIP score. Although a reduction in the magnitude of the coefficient was expected when the equation was applied to another population of scores, our experience with the PPI items indicate that intrinsic patterns are generalizable. Consequently, in addition to the CPES score, this equation was calculated for each subject in the following study.

Subjects

Twenty-four university students (16 female, 8 males) volunteered for this experiment. Their mean age was 24 years and the range was 19 to 44 years.

Procedure

The subjects were assigned sequentially to one of four conditions: sham field, 4 Hz square wave (identical to Experiment I), positive ringing wave (P-wave) and negative ringing wave (N-wave; Figure 1); there were 4 females and 2 males per condition. Each subject was escorted into the acoustic room, asked to sit in a comfortable chair and given instructions similar to those in Experiment I. Electrodes were attached by EC2 cream to the occipital (O1,O2) and temporal (T3,T4) regions. After attaching the goggles the modified motor cycle helmet (that contained the 4 sets of small reed solenoids) was placed around the subject's head. The instruction were repeated. Before the experimenter left the room, the exotic sounds tape was activated, the red light was turned on and the chamber lights were extinguished.

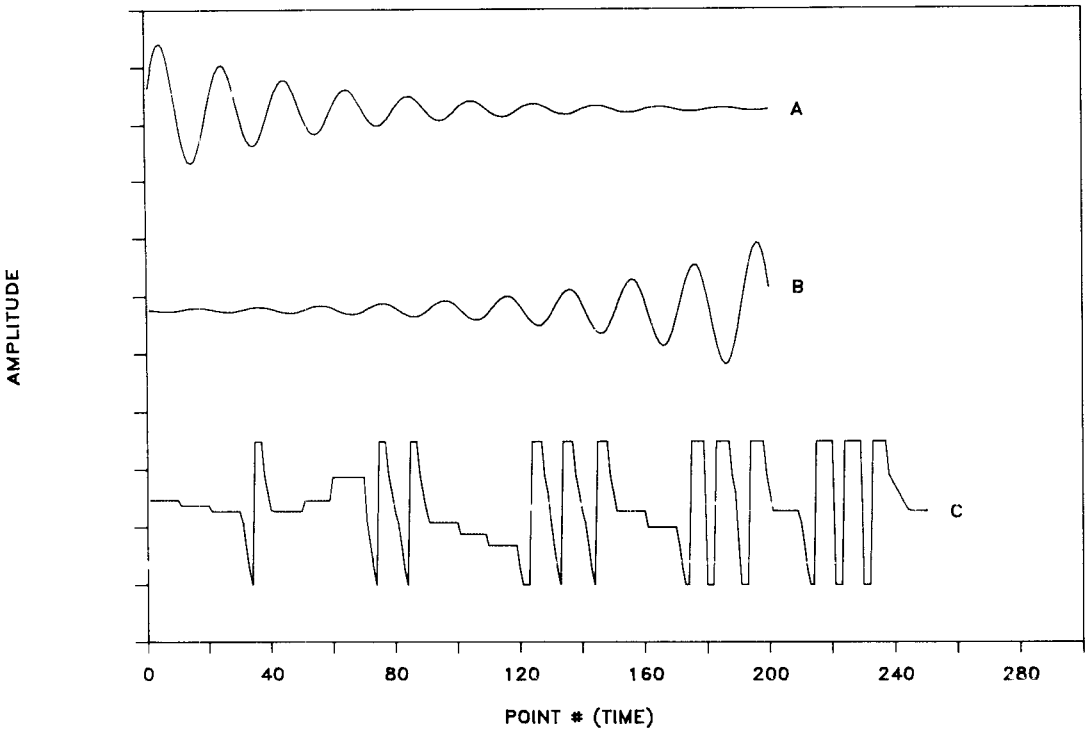

Figure 1. Computer generated configurations of: a) the "negative" ringing or dampened wave, b) the positive ringing wave, and c) the "burst firing" pattern. a) and b) were employed in Experiment I while c was employed in Experiment III. Horizontal axis refers to milliseconds.

Subjects were exposed to one of four conditions. Two of the field patterns were generated by complex wave form software (designed by second author) through a Zenith 159 computer. The printer port was connected to an interface that was composed of a digital to analogue converter (DAC) and a d.c. (operational) amplifier. This signal source was sent to the signal

distribution interface (semiconductor switches) that was controlled by the Gerbrands sequencer used in Experiment I. From the sequencer the signal was sent through the patchcord panel of the chamber into the solenoid configurations of the helmet.

The two patterns (Figure 1) were identical in shape except that one displayed a positive ring resulting in an escalating (natural log) amplitude of each sine-wave over time. The other pattern, a negative ring, dampened with time. These patterns were generated 4 times per second as the field presentation rotated through the 4 solenoids once every 2 seconds. The third group was exposed to the 4 Hz square wave through the function generator utilized in Experiment I while the fourth group (sham-exposed) never received any field exposure. The same procedures were employed; however the cable to the helmet had been disconnected.

Unlike Experiment I, the field exposures were 15 minutes in duration; they were preceded and succeeded by 5 minutes of no field. During the exposure the temporal and occipital EEG activity was monitored continuously; the third channel of the P79 Grass instrument was used to verify the presence and or absence of the field conditions as well as the integrity of their forms. Statements by the subjects were recorded and maintained for future analyses. At the end of the exposure, the SEQ was administered according to the procedure in Experiment I.

(In addition, the subjects were told that sometimes people report unusual dreams after these experiences. To discern if this is correct, the subjects were asked to keep any notes about any such experiences and to expect a call from the experimenter in about two days.)

For each subject the CPES score and suggestibility equation were calculated from the PPI that had been given within one week of the treatment. The mean and standard deviation of CPES scores were 26% (15%). An experienced clinical neuropsychologist, who routinely interprets EEG records (about 150/year) involving a comparable montage was asked to rate each record along a 3 point scale. The amount of alpha rhythm time, as defined by discriminable synchronous activity between 8 and 13 Hz, within the temporal and occipital record was determined according to 0 (less than 5%), 1 (5 to 20%) 2 (21 to 50%) and 3 (greater than 50%) for the last 20 minutes of the record. The relative numbers (0-3) of fast frequency bursts within the temporal lobe and occipital transients that generally reflect motor movements were also determined for each record.

The correlation (Spearman rho) of the ratings of alpha rhythm duration between the two lobes for this population was 0.62 ($p < 0.001$). Temporal alpha time was negatively correlated (-0.55) with the ratings of fast frequency bursts while the amount of occipital alpha time was negatively correlated (-0.79) with the index of motor movements. There was a significant (rho=0.50) correlation between the fast frequency bursts and occipital movement indices.

Analyses of variance as a function of condition and gender was completed for each cluster and for EEG scores. A two way analyses of variance, with one level repeated (the clusters) was also performed. After covarying for the effects of CPES and suggestibility scores, these analyses were executed again.

Table 2

Means and standard deviations for scores on various clusters of experiences during exposures to the sham field or to 1 mG 4 Hz square wave, 4 Hz positive-ring complex wave or 4 Hz negative ring complex fields that were applied across the temporal lobes for about 20 min (n=6/condition).

Cluster	Sham		Square		P-ring		N-ring	
	M	SD	M	SD	M	SD	M	SD
Vibrations	.8	.5	1.0	.5	1.1	.5	.7	.6
Depersonal.	.9	.5	.9	.4	1.2	.4	.9	.5
Emotions	.2	.5	.3	.4	.4	.4	.3	.3
OOBE	.6	.5	.7	.7	.4	.5	.3	.4
Old memories	.7	.6[a]	.7	.4[a]	1.3	.7[b]	.8	.6[a]
Intrusions	.2	.2	.5	.4	.5	.6	.3	.4
Total	.6	.3	.6	.4	.8	.4	.5	.3
Upper Visual Field	17%		50%		86%		60%	

a vs b p <0.01

Results

The means and standard deviations for the clusters and visual field indicator as a function of the four conditions are shown in Table 2. There were no statistically significant group (all df=3,20) differences for any of the six clusters. Females endorsed more items within the vibration [F=3.39] and depersonalization [F=4.61] clusters than did the males (dfs = 1,20). There were no statistically significant gender by condition interactions. The tendency for the subjects within the P-ring condition to report more visual experiences in the

upper visual field (86%) compared to the sham-exposed group (17%) approached significance [chi-square=6.91, df=3;, p <.10].

Covariance for CPES and Suggestibility before the analyses of variance revealed a statistically significant [F(3,18)=5.78; 35%] group difference for the old memory cluster only. The covaried means for the sham, 4 Hz square wave, 4 Hz positive ringing wave and 4 Hz negative ringing wave were 0.7, 0.6, 1.3 and 0.3, respectively. A posteriori analyses indicated that only the positive ringing wave group differed ($p < 0.05$) from the other three groups who did not differ from each other. Only the CPES covariate displayed a positive slope and was statistically significant [$F(1,18) = 11.46$, $p < 0.01$; an additional 33% of the variance]; suggestibility was not significant [$F < 1$].

The means and standard deviations for the EEG ranks for each lobe were: temporal alpha: 1.6(1.0), temporal fast frequency: 0.4(0.9), occipital alpha: 1.1 (1.0), occipital noise: 0.4 (0.9). Analyses of variance from the rank of alpha and the fast frequency or noise time over the temporal and occipital lobes as a function of condition demonstrated a significant group difference only for the fast frequency activity within the temporal lobe region [$F=4.19$, $p < 0.05$]; post hoc analyses indicated the effect was due to more frequent incidence of these displays within the sham-exposed group relative to all three field groups. The temporal lobe alpha rhythm time approached significance [$F=2.43$, $p < 0.10$] and was due exclusively to the more abundant alpha time for the group exposed to the positive-ring compared to the other three groups. Covariance for CPES and suggestibility did not enhance or diminish the strength of the results.

Experiment III

Several studies (8,12) have suggested that normal people who display elevations in temporal lobe signs also experience enhanced periods of positive affect and meaningfulness. Although there is no direct evidence for human subjects, animal studies indicate that some components of the limbic system contribute to the release of endogenous opiates such as the enkephalins and endorphins. One limbic structure, the amygdala, contains enhanced numbers of delta opiate receptors; they are associated with the euphoria and positive affect of opiate experiences.

Liebeskind and his colleagues (e.g, 17) reported that the interstimulus interval of current induction was a potent determinant of the release of opiates in rats. Whereas continuous exposure (3 minutes) to 60 Hz electric shock did alter opiate release, 60 Hz electric shock presented for 1 second every 5 seconds for 30 minutes significantly enhanced opiate related effects. We reasoned that a similar interstimulus pattern might affect human subjects.

Consequently we designed a field pattern (Figure 1c) that simulated the burst firing pattern of human amygdaloid neurons. We concluded that direct measures of analgesia (e.g., nociceptive thresholds) from endogenous opiates could be disconcerting and disrupt the subjective profile. However we have measured anger and aggressive displays following the cognitive disruption of a very pleasant experience as indices of hedonistic intensity; the disruption generates frustrative aggression. In this experiment the subjects were allowed to enter a comfortable subjective experience. He or she was then

interrupted and requested to continuously generate a narrative whose theme was determined by the experimenter. The validity of this procedure was indicated by the verbal content of the subjects in response to this disruption.

Because people with elevated CPES scores utilize words with more pleasant semantic ratings (12) to describe spontaneous narratives within this setting, we hypothesized that disruption of subjects who: 1) display above average CPES scores and 2) are exposed to the "hedonistic" field condition, should report the greatest emotional experiences. Because we decided to calculate their scores after the exposure, in order to minimize possible bias, a larger sample of subjects was required in order to insure that the numbers of subjects per condition were sufficient.

Subjects

A total of 37 volunteers (18 males, 19 females) were included in this experiment. They were recruited from undergraduate psychology courses. Their mean age was 22 years and the age range was between 19 and 30 years.

Procedure

Subjects of each gender were assigned in random order to one of two conditions that differed only in the period of presentation of the same wave form (Figure 1c). Each subject received the same instructions as employed in Experiment II. Occipital and temporal lobe EEG activity was again recorded and the presence or absence of the field was monitored. Unlike Experiments I and II, the Astral Sounds Tape was not utilized to standardize auditory input. Our rationale was that

hedonistic experiences should be heightened when they are driven by introspective and idiosyncratic factors rather than by stimuli that may have substantially less personal salience.

The fields were presented in the following sequence: 5 minutes no field, 10 minute field, 5 minutes no field, 10 minutes field and 5 minutes no field. Each subject received the burst-firing pattern field either continuously during the 10 minute field periods or for one second once every 4 seconds during the field periods; there were four burst-pattern cycles per second.

Comments and experiences by the subjects were tape recorded according to previous procedures. Unlike the previous experiments, at the end of the first field block, the experimenter interrupted the subject through the chamber microphone and instructed him or her to pretend that they were alone in a space ship. In order to maintain contact with other people, continuous reporting of their subjective experience was required. This request generated narratives that were more than 3 times the length of the usual sequence.

The PPI was administered within one week of the experiment. The CPES and suggestibility scores were determined by computer after the experiment was completed and the SEQ data had been loaded. The mean and standard deviation for the CPES score were 30 (19)%, which is within the normal range. This resulted in 7 and 12 subjects within the below and above average CPES score for the continuous field group and 9 subjects each within the below and above average group for the intermittent field exposure.

The internal consistency of the EEG ratings, using the same procedure as employed in Experiment II, was determined by

intralobe and crosslobe correlations. For all subjects, the correlation (rho) between alpha time across the two lobes was 0.45 ($p < 0.01$); there was no significant correlation between the measure of fast frequency activity within the temporal lobe and occipital motor activity ($r=0.12$); however the later was significantly correlated (-0.50, $p < 0.01$) with alpha time within the same lobe. The suggestibility cluster was correlated 0.40 ($p=0.01$) with the occipital alpha rating and 0.07 (n.s) with the temporal alpha rating.

Results

One way analyses of variance showed no statistically significant group differences for the six clusters [all $Fs < 2$]. However when the CPES and suggestibility scores were covaried [$F(1,33)=6.12$, $p < 0.05$], the group exposed to the continuous field reported more experiences on the vibration cluster [$F(1,33)=6.77$, $p=.01$; 15%] than those exposed to the intermittent field. The suggestibility covariate was not significant [$F(1,33)=1.77$, $p > 0.05$]. No other group differences emerged; covariance indicated a significant positive relationship between scores on the old memory cluster and CPES [$F(1,34)=4.23$, $p < 0.05$] only.

The means and standard deviations for the cluster cores for the two conditions (psychometric score and field presentation pattern) are shown in Table 3. Two-way analyses of variance as a function of temporal lobe sensitivity (above or below the mean CPES score) and field condition (continuous vs intermittent) demonstrated that subjects who scored above the mean on the CPES scale reported more frequent experiences from the vibration [$F(1,29)=7.97$, $p < 0.01$; 23%], emotion ($F= 5.08$,

Table 3

Means and standard deviations for the clusters of experiences that were reported during either continuous or intermittent (1 sec every 4 sec) exposures to 1 mG burst-firing patterns across the temporal lobes (n=7-12/group).

	Continuous				Intermittent			
	Low CPES		High CPES		Low CPES		High CPES	
Vibrations[c]	1.1	.5	1.4	.6	0.6	.5	1.4	.3
Depersonal.	0.9	.5	1.0	.4	0.6	.5	1.0	.2
Emotion	0.6	.4[a]	0.5	.4[a]	0.2	.3[a]	1.0	.6[b]
OOBE	0.2	.3	0.4	.3	0.2	.2	0.4	.3
Old memories	0.8	.6	1.1	.5	0.8	.4	1.3	.5
Intrusions	0.2	.3	0.3	.4	0.2	.2	0.3	.2
Total	0.6	.3	0.8	.3	0.4	.2	0.9	.1
Upper Visual	67%		58%		60%		67%	
Optimal Cluster	1.7	.9	1.0	.8	0.6	.5	2.8	1.2

[c] continous vs intermittent, p=.01

a vs b; p <0.01

p<0.05), OOBE (F=4.89, p<0.05; 15%) and old memories (F=5.83, p<0.05; 15%) clusters than subjects whose CPES scores were below the mean. None of the clusters revealed a main field effect. However as predicted, a statistically significant field by temporal lobe sensitivity interaction was evident [F(1,29)=7.98, p<0.01] for the emotion cluster only.

To determine the optimal strength of this effect all items from the exit questionnaire were analyzed separately by ANOVA; three items displayed significant group differences. They were

"I experienced anger", "I experienced terror or fear" and "There were images from a dream I've had". The combined scores of these three items were called the "optimal cluster" and were analyzed by ANOVA. The F value for the significant interaction between field condition and temporal lobe sensitivity was 20.72 ($p < 0.01$); again there was no main field effect.

Three way analyses of variance (field, CPES dichotomy) with one level repeated (cluster) revealed the expected difference between clusters [$F(5,165)=42.56$, $p < 0.001$]. The cluster means in descending order of amplitude were: vibration, old memories, depersonalization, emotions, out-of-body experiences and thought intrusions. Subjects who scored above the 50th percentile of the CPES mean reported more experiences on all clusters [$F(1,33)=12.43$, $p=.001$] than those who scored below this value. Although there was no significant main effect for field condition [$F(1,33) < 1$], the interaction between the score on all clusters with the dichotomous CPES score was significant [$F(1,33)=4.20$ $p=.05$]. The latter effect was due primarily to the subjects with above average CPES scores in the intermittent field condition; these subjects reported twice the "intensity" of experiences relative to the subjects who were exposed to this field but displayed CPES scores below the mean.

The means and standard deviations (in parentheses) for the EEG measures (ranks) were: temporal lobe alpha: 1.0 (1.1), temporal lobe fast frequency: 1.0 (1.1), occipital alpha: 1.5 (1.3) and occipital motor noise: 0.4 (0.9). Analyses of variance for the ranks of the alpha rhythm time and the incidence of fast frequency and movement episodes over the temporal and occipital lobes according to field condition and temporal lobe designation (sexes combined) revealed a

significant increase [$F(1,27)=4.26$, $p < 0.05$] in the rank of fast frequency episodes within the group that had been exposed to the intermittent field (0.7) vs the continuous train (0.2). The larger numbers of motor artifact episodes over the occipital lobes of the group exposed to the intermittent field approached significance ($F=3.71$, $p=.06$]. The effect was dominated primarily by subjects whose CPES scores were above the mean and who were exposed to the intermittent field. There were no other significant main effects or interactions.

Phenomenological Profiles

Our research with weak biofrequency magnetic fields and subjective experiences have indicated that the phenomenological profile of a person within the experimental setting is a function of his or her temporal lobe sensitivity (as measured by possible temporal lobe signs), the demand characteristics of the setting and the magnetic field patterns. Of the three variables, the neuropsychological characteristics of the subject rather than the demand characteristics or the field parameters accommodate most of the variance. To determine how various types of temporal lobe signs contributed to the numbers of experiences within the clusters of reports that occurred within the experimental setting, the following analyses were completed.

Method

Data

SEQ and PPI data of the 61 subjects who were exposed to the magnetic field treatments from Experiments II and III were aggregated.

Procedure

The major clusters and subclusters from the PPI were calculated for each of the subjects. The major clusters involved control items (n=16) complex partial epileptic signs (CPES, n=16)), interictal-like behaviors (ILB, n=14) and affective-dissociative indicators (ADI, n=22). Items from the control and CPES and ILB clusters have been published elsewhere (11). The ADI cluster included items such as "Sometimes I am sure people can tell what I am thinking", "Sometimes I am so full of pep and energy I feel as if I am superhuman" and "I am very religious (more than most people)".

The subclusters, each containing between 3 and 7 items were calculated from the above items and additional items that are considered correlative to temporal lobe signs, e.g., suggestibility. The names of the clusters, based upon both item content and construct validity (correlations with other scales that measure this concept), were fear, perseveration, limbic motor stereotypes, automatic behaviors, writing, meaningful experiences, visual experiences, depersonalization, auditory-vestibular sensations, sense of a presence, suggestibility, olfactory sensations and hypomania.

In addition three other clusters were calculated; they were composed of items that had been shown to optimally predict the amount of alpha rhythm duration from the temporal lobes (TEMEEG, n=8 items), alpha rhythm duration in both the occipital and temporal lobes(ALPHOT, n=9 items) and over the temporal lobes when the eyes were closed (TEMAC). The three items that composed the latter were "While sitting quietly, I have had uplifting sensations as if I were driving quickly

over a rolling road", "I have been known to walk in my sleep" and "At least once in my life, just before falling down, I have had the intense sensation of a smell from childhood". Scores on these clusters had displayed correlation (r) coefficients between 0.40 and 0.70 with the amount of alpha rhythm time in other groups of students or special populations such as poets (11,17).

In order to accommodate the propensity for "yes responding", partial correlation analyses (with the scores on the control cluster held constant) were completed between each of the clusters from the SEQ and the scores on the major PPI clusters and the clusters of items that had best predicted alpha rhythm duration in other studies. Stepwise multiple regression analyses were completed so that we could determine which of the subclusters of the PPI best predicted scores on the phenomenological clusters that were reported in the experimental setting. Although the subject size was small, we completed a preliminary canonical correlation between the six SEQ clusters and the 13 subclusters of the PPI in order to examine the consistency of loading upon the most singular root. All analyses were completed on SPSSX software and a VAX computer.

Results

For comparisons with subsequent studies, the percentages of subjects that reported the experience at least once on the SEQ, are shown in Table 4. As can be seen a number of experiences, often considered primary correlates of altered states or mystical experiences, were quite prevalent within the experimental setting. There was no significant correlation

Table 4

Percentages of subjects (field exposed only, n=61) who reported the experience for the 20 items.

Item	Percentage	Short Description
1	80	felt dizzy or odd
2	36	felt a presence
3	76	tingling sensations
4	65	saw vivid images
5	67	pleasant vibrations in body
6	46	felt detached from body
7	0	inner voice call name
8	20	experienced anger
9	37	experienced sadness
10	20	ego-alien thought intrusion
11	50	heard a ticking sound
12	09	odd smells
13	40	experienced terror or fear
14	13	odd tastes
15	69	felt somewhere else
16	42	thoughts from childhood
17	77	same idea kept repeating
18	36	felt as if spinning around
19	32	images from a dream
20	16	brightness of red light fluctuated

Table 5

Partial correlation coefficients between the major phenomenological clusters from the experimental setting and the major possible temporal lobe sign scores and items that were optimally correlated with alpha rhythm activity in other studies (n=61 subjects).

SEQ	PPI Clusters					
Cluster	CPES	ILB	ADI	TEMEEG	ALPHOT	TEMAC
Vibration	0.31	0.22	0.24	0.30	0.37	0.22
Depers	0.18	0.15	0.05	0.24	0.19	0.24
Emotions	0.29	0.26	0.43	0.08	0.20	0.10
OOBE	0.37	0.39	0.12	0.21	0.24	0.32
Memories	0.42	0.24	0.13	0.28	0.29	0.26
Intrusion	0.23	0.28	0.12	0.10	0.17	0.12

$r > 0.20$, $p < 0.05$

$r > 0.29$, $p < 0.01$

$r > 0.33$ $p < 0.001$

(r=0.12) between the subjects' responses on the control cluster from the PPI and the total number of affirmative endorsements for the 20 exit items.

The first order partial correlation coefficient (controlling for "yes" responding) between the phenomenological clusters from the SEQ the major clusters of the PPI and the items that best predicted EEG activity in other studies are shown in Table 5. The CPES cluster was positively and significantly correlated, regardless of magnetic field pattern, with the intensity of all SEQ clusters except depersonalization. The

affective-dissociation indicators were positively correlated only with the emotion cluster. The depersonalization cluster was weakly correlated with items that had been significantly associated with the amount of alpha rhythm time over the temporal lobes in other studies (11,17).

Step-wise multiple regression analyses (MR=multiple r; B=partial regression coefficient) indicated that: 1) the intensity of SEQ vibration experiences were positively associated [$F(1,58)=6.42$, $p=0.01$] with scores on the hypo-mania (MR=0.32; B=0.59), 2) SEQ depersonalization was predicted [$F(2,57)=4.88$, $p=.01$] by suggestibility (B=-0.50) and perseveration (MR=0.38; B=0.61), 3) SEQ emotions were predicted by the meaning cluster [$F(1,58)=10.03$. $p=.002$, MR=0.38; B=0.88], 4) SEQ OOBE was predicted [$F(1,58)=15.29$, $p<0.001$] by auditory-vestibular experiences (MR=0.46; B=0.70), 5) SEQ old memories [$F(3,56)=6.43$, $p<0.001$] by visual experiences (B=0.89), fear (B=-0.69) and olfactory experiences (B=0.98; MR=0.51) and 6) SEQ intrusive thoughts were predicted [$F(1,58)=9.73$, $p<0.01$] by limbic motor stereotypes (B=0.55, MR=0.38).

The exploratory canonical correlation between the six SEQ clusters determined by experiences within the experimental setting and the 10 PPI subclusters revealed several roots. The major root (r=0.71) was significantly (r>0.40) loaded by emotions, OOBE, old memories and intrusive thoughts from the SEQ and by the limbic motor stereotypes, meaningful experiences, writing, auditory-vestibular and olfactory experiences from the PPI subclusters.

Discussion

The results of the present and previous (1) experiments strongly indicate that phenomonenological experiences can be differentially influenced by weak biofrequency magnetic fields when they are applied through the human brain. Evoked subjective experiences were presumably correlated with the electrical currents that were preferentially induced within the electrically sensitive and labile structures of the temporal lobes. The experiences were similar to those elicited by surgical stimulation of deep temporal lobe structures and were of sufficient intensity to effect the subjects' responses on a questionnaire after the exposures had been completed.

Although there has been frequent historical reference to subjective effects during an exposure to a 100 to 1000 nT, extremely low frequency magnetic field, they have not been systematically evident. This variability could reflect the inappropriate setting in which the fields were applied. We have found that conditions that encourage introspective cognitive processing are essential to allow detection of these relatively weak effects. Deprivation of visual input, a normalized acoustic environment (in this instance, generated through a particular audiotape) and a comfortable setting, facilitate this condition.

Upon retrospect these special environments should be essential to allow the weak induction effects from magnetic fields with optimal temporal structure to compete with the massive neuroelectrical processing that occurs even during passive cognitive states. Modern PET (positron emission tomography) measurements have clearly shown that both the intensity

and the localization of cerebral metabolic activity are sensitive to the ambient environment, the sensory modality and the cognitive strategies involved to interpret the input (18).

Experiment I demonstrated that magnetic fields, rotated bilaterally once every 2 seconds over the subject's temporal region, evoked stronger and more frequent experiences than when the same frequency and intensity field remained fixed within the application area. Experiences emerged, suggesting ego-alien phenomena, where some subjects felt that the sensations "were not from their own mind". Similar intrusive experiences have been reported in epileptic patients when the amygdala was stimulated during ongoing cognitive processes (19).

The mechanism by which the larger numbers of reported experiences were evoked by the rotating field is likely to involve the enhanced volume of neuronal space within which the currents from the applied fields were induced. However the frequency of rotation (once every 2 seconds) is within the range to facilitate resonance with the slow potentials that are generated by glial cells (20). These cells modulate large populations of neurons, especially within the amygdala and the hippocampus. Because glial cells are connected in a pervasive syncytium, even marginal stimulation of this panencephalic network could have altered the recruitment patterns of neuronal ensembles and consequently evoked more subjective experiences.

The two-second rotation period for the entire field pattern had been selected based upon the contemporary knowledge of glial cell electrical properties and upon our experience with 0.5 Hz rotating magnetic fields (21). In a series of unpublished studies between 1971 and 1972, human subjects relaxed in a prone position and placed their heads between two

rotating horseshoe magnets (100 mT). These subjects (n=6) reported enhanced visual imagery, especially from the upper peripheral visual fields. These experiences were not phosphenes and were often associated with intense fear. Voluntary consumption of the serotonin competitor, LSD (lysergic acid diethylamide), in dosages sufficient to elicit psychedelic states, intensified the visual experiences such that perceptions of moving yellowish-green and purplish lights and matrix patterns were reported during the field exposure periods only.

In the present study we suspected that an ELF field superimposed upon a more slowly changing spatial rotation would also enhance the intensity of the effect without requiring the magnitudes required during the unpublished experiments. Still slower rotations may evoke stronger effects. The spatial rotation was too quick to simulate the depolarization processes that are correlated with Leao's spreading depression. It is associated with changes in the d.c. potentials upon which the much faster (ELF range) microvolt EEG potentials are superimposed. In light of the suspected clinical correspondence between spreading depression and both migraine and dissociated states, pursual of this mechanism would require caution.

That the spatially varying magnetic fields rather than the stable fields were specifically enhancing temporal lobe structures is strongly indicated by the significant increase in references to upper visual field references in the former condition. Enhanced visual sensations or images in the upper visual fields are clinical indicators of stimulation within the temporal lobe because Meyer's loop of the geniculo-calcarine

pathway infringes on its boundary enroute to the occipital cortex (13).

The only frequency-specific effect reported in Experiment I was the enhanced number of "thought intrusions" reported by subjects exposed to the 16 Hz field relative to the 4 Hz field. The effect appears more specific to frequency than to the form of the applied field because there was no statistically significant interaction between the frequency and field modes. Why only this cluster responded to the frequency specificity is not clear, although one cannot exclude at this time either statistical artifact or the confounding effects of the elevated strength of the fields within the 16 Hz condition.

Experiment II was a partial confirmation of our hypothesis. We wanted to clearly show that any specific subjective effect was due to the wave form not confounded by field intensity. Consequently subjects were exposed to either the forward or reverse pattern of this wave or to the 4 Hz or sham conditions. Only the numbers of visual memory experiences were clearly enhanced during the presentation of the wave form that was characterized by an exponential increase in energy; exposure to the same field pattern, in reversed temporal order (the mirror image), evoked changes that were not significantly different from the 4-Hz square wave or sham field condition.

The results are not convincing intuitively. The explanation for the lack of effect within the other five clusters requires postulation of a specific influence of the 4 Hz positive ringing field upon the brain process that were associated with "old memories". Although such specificity should exist theoretically, we are cautious to conclude that it was found upon so quickly. In addition, the effect of the

exponentially increasing wave form was evident statistically only after the variance associated with subjects' scores of possible temporal lobe signs was removed.

The requirement for such covariance has two important implications. First, the effect from the applied fields was so weak that it was masked by the individual variability in the propensity to experience old memories. Second, because the CPES scores were positively associated with the scores on the "old memories" cluster, they may share the same source of variance. Together these results suggest that the applied fields may be stimulating the same portions of the brain that are responsible for the person's history of possible temporal lobe signs and symptoms.

The rationale for Experiment III had been based upon animal experiments in which opiate-like behavior was induced differentially by the temporal pattern of electric footshock to rodents. Presumably this optimal correlative volley of afferent stimulation evoked release of the endogenous opiates. We did not measure opiates directly in this study but inferred the hedonistic quality of the experience by interrupting the subject after 15 minute of exposure to the fields.

As predicted those subjects who displayed above average numbers of possible temporal lobe signs (before the experiment began) and were exposed to the intermittent field pattern displayed more responses for only one of the six cluster of experiences: emotions. Qualitatively, these subjects vocalized their displeasure at the interruption. On the other hand subjects whose temporal lobe signs were below average did not report these experiences.

If one assumes that enhanced numbers of temporal lobe signs are correlated with enhanced ratios of burst firings or "microseizures" (9) in the amygdala and that the field pattern elevated endogenous opiates, then a possible mechanism might exist to explain this effect. The amygdala contains copious numbers of delta opiate receptors through which euphoria and pleasurable experiences are mediated (22). Field induced release of opiate compounds would have facilitated the activity of those subjects who displayed enhanced electrical lability before the experiment began. That items from our temporal lobe signs inventory is correlated with amygdaloid function has been suggested by their positive correlation with the facility for delayed crossmodal (tactile-visual) matching (23). This enhancement is a predicted consequence of the continuum of sensory limbic hyperconnectism that has been predicted by Bear (3).

We were surprised at the statistical size of the effect. Typically, the level of field effects with this paradigm have been sufficient to explain about 20 to 30% of the variance for the main effects, using the numbers of subjects that we typically employed. The intermittent field presentation-above average temporal lobe signs effect was substantially larger. Reanalyses of the data from Experiments I and II, employing the dichotomy of below and above average CPES scores, did not reveal comparable effects. The wave pattern that was designed to simulate the "burst firing" feature of amygdaloid neurons appears to have been a necessary condition.

The differential effects between the <u>same wave pattern</u> presented either continuously or intermittently add another dimension to the potential parameters that could influence

subjective experience. To date, because of dependence upon commercial function generators, most experimenters have employed magnetic field patterns that have generated temporal blocks of current induction. If organismic response to both the stimulus pattern and the interstimulus interval of application of the pattern are similar to the consequences of more routine modalities, e.g., vision and audition, then classic psychophysical issues, such as habituation and contrast effects might be pursued. Habituation effects have been reported. McGivern, et. al. (24) indicate that some biological effects of ELF magnetic field exposure peak during the first 15 to 30 minutes and then significantly diminish thereafter.

Access to computer-programmable signal patterns, as exemplified in Experiments II and III, allows pursuit of specific mechanisms and the utilization of specific paradigms. For example, the human amygdala is sensitive to changes in stimulus input. "Odd ball" tasks, that involve the occasional presentation of an anomalous pattern during a temporal stream of redundant stimuli, can evoke power changes in electrocortical activity. They are often manifested as the P300 (positive contingent, 300 msec) component of evoked potentials. If this structure is detecting weak magnetic field patterns, then an applied magnetic field sequence that simulates the odd ball task should enhance or facilitate the occurrence of the subject themes that are associated with amygdaloid stimulation.

That the specific field effects reported in the present experiments were due to indirect suggestibility is unlikely. Covariance for a series of items that were moderately correlated with objective measures of suggestibility (the hypnosis induction profile, HIP) in another study never

displayed statistical significance. The validity of this measure was also supported by the positive correlation between this score and the amount of alpha rhythm time over the occipital lobes; such positive moderate relations have been reported frequently (25).

The enhanced fast frequency measures over the temporal lobes within the sham-exposed group relative to the field exposed groups in Experiment II is similar to that reported previously (1). This EEG pattern, which appears to be strongly associated with displays of subjective distress or negative affect, suggests that the addition of the magnetic fields reduced the boredom associated with the setting even though the sham field subjects were exposed to the exotic music. Similarly, the enhancement of these indicators of subjective distress or negative affect in the group (inter-mittent field exposure) that displayed the greatest irritabi-lity and emotion in Experiment III would be also be expected.

The results of the phenomenological profiles indicated that normal people, when placed in exotic, introspective-oriented settings, report experiences that suggest temporal lobe signs and symptoms. The multiple regression analyses indicated that the intensity of the experience within this environment is affected by the intensity of temporal lobe lability before the experiment began. Because test-retest reliability of the PPI items are relatively stable over time [10 days ($r>0.90$); 100 days ($r>0.70$)], this "sensitivity" is likely to be a persistent feature of the subject's personality.

Our provisional canonical analysis was implemented to discern which clusters from the SEQ and the PPI were loaded on the same source of variance (or root). It indicated that the

clusters that were significantly affected by the field treatments were related to the subject's historical experiences with the dominant aggregate of signs and symptoms reported by people who have verified limbic lability. They include stereotyped (dissociative) behaviors, widening of affect (deep meaning to personal and odd events), the propensity to keep detailed notes of their experiences, unusual vibrational or auditory sensations (often coupled with great personal or mystical significance; and olfactory aura. However none of our subjects reported a history of epilepsy and none of the EEG records ever indicated the existence of paroxysmal or focal processes.

Previous attempts to discern phenomenological correlates of ELF magnetic field exposures have ignored the issue of variable sensitivity. We have found that factors related to psychometric measures of suggestability may affect field-specific sensitivity; it may also be mediated by cognitive style (1). Considering the highly significant role of cognitive structure and personality profile in responses to even the more powerful neurocognitive interventions, such as antidepressants and anxiolytics, there is no a priori reason to assume that such differences should not exist for magnetic field detection.

As mentioned previously (1), one of our major goals of this research is to understand the functional connections of the human limbic system by discerning the patterns of changes in cognitive processes when weak but discrete increments of energy are induced within the brain. Our results indicate that this paradigm might also be useful in determining the effectiveness of weak, biofrequency magnetic fields, including those generated within the man-made and natural environment.

REFERENCES

(1) Ruttan, L. A., Persinger, M. A. and Koren, S.: Enhancement of temporal lobe-related experiences during brief exposures to milligauss intensity extremely lowfrequency magnetic fields, Journal of Bioelectricity, (in press).

(2) Persinger, M. A.: The modern magnetotherapies. in Modern bioelectricity, A. A. Marino (ed)., Marcel Dekker, New York, 589-627, 1988.

(3) Bear, D. M.: Temporal lobe epilepsy: a syndrome of sensory limbic hyperconnectionism. Cortex, 15, 357-384, 1979.

(4) Stevens, J. R.: Sleep is for seizures: a new interpretation of the role of phasic events in sleep and wakefulness, in Sleep and Epilepsy, M. B. Sherman, M.N. Shouse and P. Passouant, eds., Academic Press, New York, 249-264, 1982.

(5) Horowitz, M.J. and Adams, J. E.: Hallucinations on brain stimulation: evidence for revision of the Penfield hypothesis, in Origin and Mechanisms of Hallucinations, W. Keup, ed., Plenum Press, New York, 13-22, 1970.

(6) Neppe, V. M.: Temporal lobe symptomatology in subjective paranormal experients. J. Am. Soc. Psychical Res. 77, 1-29, 1983.

(7) Bear, D. M. and Fedio, P.: Quantitative analysis of interictal behavior in temporal lobe epilepsy. Arch Neurol, 34, 1977.

(8) Persinger, M. A. and Makarec, K.: Temporal lobe signs and

correlative behaviors displayed by normal populations. J. Gen. Psychol. 114, 179-195, 1987.

(9) Persinger, M. A.: Religious and mystical experiences as artifacts of temporal lobe function: a general hypothesis, Perceptual and Motor Skills, 57, 1225-1262, 1983.

(10) Isokawa-Akesson, M., Wilson, C. L. and Babb, T. L.: Structurally stable burst and sychronous firing in human amygdala neurons: auto- and cross-correlation analyses in temporal lobe epilepsy, Epilepsy Res, 1, 17-34, 1987.

(11) Makarec, K. and Persinger, M.: Electroencephalographic validation of a temporal lobe signs inventory in a normal population, J. Res. Personality (in press).

(12) Ruttan, L. A. and Persinger, M. A.: Temporal lobe signs and enhanced pleasantness scores for words generated during spontaneous narratives. Perceptual and Motor Skills, 69, 1101-1102, 1989.

(13) Reitan, R. M. and Wolfsan, D.: Neuroanatomy and neuropathology. Neuropsychology Press, Tuscon, 1985.

(14) Persinger, M. A. and DeSano, C. F.: Temporal lobe signs: positive correlations with imaginings and hypnosis induction profiles, Psychol. Rep. 58, 347-350, 1987.

(15) Ross, J. D. and Persinger, M. A. Positive correlations between temporal lobe signs and hypnosis induction profiles: a replication. Perceptual and Motor Skills, 64, 828-830, 1987.

(16) Spiegel, H. and Spiegel, D. Trance and treatment, Basic Books, New York, 1978.

(17) Lewis, J. W., Cannon, J. T and Liebeskind, J. C.: Opioid and nonopioid mechanisms of stress analgesia. Science, 208, 623-625, 1980.

(18) Pawlik, G. and Heiss, W.-D. Positron emission tomography and neuropsychological function. in Neuropsychological function and brain imaging, E. D. Bigler, R. A Yeo and E. Turkheimer, eds., Plenum Press, New York, 65-138, 1989.

(19) Mahl, G. F. Rothenberg, A., Delgado, J. M. and Hannibal, H.: Psychological responses in the human to intracerebral electrical stimulation. Psychosom. Med. 26, 337-368, 1964.

(20) Rowland, V.: Potentials, slow electrical, behavioral correlates. in G. Adelman (ed). Encyclopedia of Neuroscience, Birkhauser, Boston, 970-972, 1987.

(21) Persinger, M. A. (ed): ELF and VLF electromagnetic field effects. Plenum Press, New York, 1974.

(22) Henry, J. L.: Circulating opioids: possible physiological roles in central nervous function, Neuroscience and Biobehavioral Reviews, 6, 229-245, 1982.

(23) Sabourin, L. and Persinger, M. A.: Specific temporal lobe signs and enhanced delayed cross-modal matching performance, Perceptual and Motor Skills, 64, 309-311, 1987.

(24) McGivern, R. F., Sokol, R. Z. and Adey, W. R.: Prenatal exposure to a low-frequency electromagnetic field demasculinizes adult scent marking behavior and increases accessory sex organ weights in rats. Teratology, 41, 1-8, 1990.

(25) Fromm, E. and Shor, R. E.: Hypnosis, Adline Publishing Co, Chicago, 1972.